NASA TECHNICAL MEMORANDUM NASA TM-76370

(NASA-TM-76370) ROLE OF A DECREASE IN BODY HEAT CONTENT IN THE THERMOREGULATORY REACTION OF THE CONCHA AURICULAE VESSELS (National Aeronautics and Space Administration) 14 p HC A02/MF A01 CSCL 06P G5/52 N81-20717 Unclas 19771

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Translation of "Rol' snizheniya teplosoderzhaniya organizma v termoregulyatornoy reaktsii sosudov ushnoy rakoviny," Fiziologicheskiy zhurnal SSSR im. I. M. Sechenova, Vol. 64, No. 6, 1978, pp. 843-849.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546 SEPTEMBER 1980

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-76370		

4. Title and Subtitle	5. Report Date
ROLE OF A DECREASE IN BODY HEAT CONTENT IN THE THERMOREGULATORY REACTION OF THE CONCHA AURICULAE VESSELS	SEPTEMBER 1980
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
N.A. Slepchuk, G. V. Rumyantsev	
	10. Work Unit No.

9. Performing Organization Name and Address	11. Contract or Grant No.
SCITRAN Box 5456 Santa Barbara, CA 93108	NASW-3198
	13. Type of Report and Period Covered
	Translation

12. Sponsoring Agency Name and Address	14. Sponsoring Agency Code
National Aeronautics and Space Administration Washington, D.C. 20546	

15. Supplementary Notes

Translation of "Rol'snizheniya teplosoderzhaniya organizma v termoregulyatornoy reaktsii sosudov ushnoy rakoviny", Fiziologicheskiy zhurnal SSSR im I.M. Sechenova, Vol. 64, No. 6, 1978, pp. 843-849

(73A34737)

16. Abstract

At the oonstant ambient temperature 28-30°C the rabbit ear vessels were dilated and their temperature was 34.8/0.1°C. Administration of the 23-29° water into the stomach entailed thermoregulatory construction of the ear vessels within 15-25 min. The response occurred at various combinations of temperature changes in different parts of the body. The heat content of the rabbit body, as calculated by the blood temperature in the aorta are, reduced by 266.3 ± 26.2 cal/kg at the beginning of the response. The decrease in the organism heat content seems to serve as a signal for occurrence of a corresponding thermoregulatory response.

17. Key Words (Selected by Author(s))	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified	Unclassified	14	

NASA-HQ

UDC 612.53

ROLE OF A DECREASE IN BODY HEAT CONTENT IN THE THERMOREGULATORY REACTION OF THE CONCHA AURICULAE VESSELS

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When thermoregulatory reactions occur there is a definite interaction between the different thermosensitive regions [5, 8, 10, 11]. Neurons have been found in the hypothalamus that react to a change in the local temperature and temperature of other body regions [2,9, 12, 14, 16]. We previously demonstrated that with an increase in the body's heat content, at a certain threshold amount a thermoregulatory reaction occurs of dilation of the concha auriculae vessels that is directed towards an increase in heat emission [3, 6]. Apparently, signals from the temperature sensors that are localized in different body sections are integrated by the central nervous system, and provide information in relation to the level of the thermal condition of the entire organism or heat content. /843**

This work set the task of determining the threshold amount of heat content decrease necessary to engage the thermoregulatory reaction of vessel constriction in the rabbit concha auriculae.

Technique

The experiments were conducted on rabbits weighing 2.5-3 kg.

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**Numbers in margin indicate pagination in foreign text.

The animals for two weeks, four hours a day were preliminarily trained to sit quietly in a special machine that restricted the animal's mobility, but permitted it to adopt a natural position. In the beginning thermocouples were implanted into the medial preoptical region of the animals' hypothalamus and into the cerebral cortex. The fabrication and implantation of thermocouples into these cerebral regions have been previously described [4, 6]. Within a week after the aforementioned operation the animals underwent surgery for gastric fistula according to the classic technique [7]. The end of the fistulous tube that was made of polyvinyl chloride plastic was placed on the lateral surface of the abdominal wall. Within 10 min. the thermocouples were implanted into the aortic arch, in the anterior vena cava, into the muscles and under the skin. These thermocouples were made of copper wire 0.08 mm in diameter and of constantan 0.10 mm in diameter. The thermocouple junction remained free and was thoroughly insulated with organic glass dissolved in chloroform. After the organic glass was dried, the thermocouple junction was additionally insulated with cellulose nitrate varnish. A skin cut was made in the cervical section in order to insert the thermocouples into the aortic arch. The common carotid artery was prepared. It was pinched in two places. Between the clamps the vessel was punctured with a thin surgical /844
needle into which the thermocouple was inserted. After the clamps were removed, the thermocouple was advanced to the aortic arch a distance of about 5.5 cm. The thermocouple was inserted into the anterior vena cava through the puncture in the external jugular vein. The thermocouples were carefully fixed with the help of silk ligatures to the vascular adventitia and were additionally sewn to the underlying tissues. Then a thermocouple was inserted into the region of the musculus latissimus dorsi to a depth of 1-1.5 cm, and under the skin above it. The ends of the thermocouple with the help of a special needle were lead out under the skin on the animal's back and were placed in a box that was fixed to the back muscles. The temperature in the rectum was measured

at a depth of 5-6 cm. The electromotive force of the thermocouples was intensified with the help of a F-116/2 photoelectric amplifier and was recorded on the tape of a 24-channel electronic, automatic potentiometer EPP-09 [1]. The sensitivity of the temperature measurement was 0.01°, the error was 0.5%. The experiments were started on the fifth day after implantation of the thermocouples into the vessels, and were conducted in a chamber 20.7 l in volume. Air was constantly blown through the chamber at a velocity of 2.5 l/min with the help of a PR-7 type air blower. The temperature in the chamber during the experiment was maintained at a constant assigned level, and fluctuated from experiment to experiment in limits of 28-30°. A schematic illustration of the procedure for inserting water into the stomach is presented in fig. 1. Before the experiment,the cap was removed from the fistulous tube 2, through which rubber balloon 1 was inserted with capacity of 100 ml. With the help of a rubber plug 4 it was secured in the fistulous tube. In order to introduce water into the balloon polyethylene tube 3 was installed into the plug. It went outside the chamber. Part of this tube (9cm) was located in the balloon, 35 cm were placed inside the chamber, and 25 cm outside the chamber. A 100 ml syringe was attached to the tube. Water at a temperature of 23-29° was introduced through it into the balloon at a rate of 10 ml every 2.5 min. During the entire experiment the water temperature in the balloon was measured, and the temperature of the entering water. For this purpose one of the thermocouples T_1 was placed at the end of the tube inserted into the balloon, and the other T_2 was located at the site where the plug fixed the balloon in the fistulous tube.

The quantity of heat given off by the animal's body to heat the water in the stomach (Q') was computed according to the formula

$$Q' = cm(T_1 - T_2) + cm(T_3 - T_4) + \ldots, \qquad (1)$$

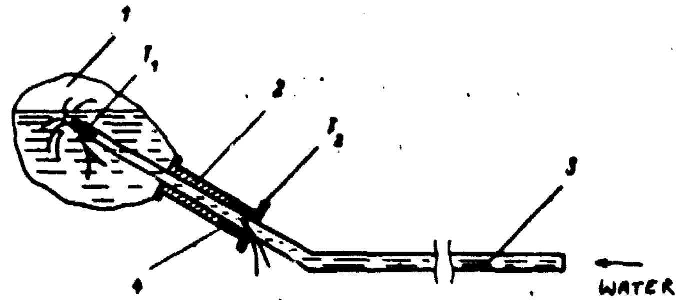

Figure 1. Plan for Cooling Rabbit by Introducing Water into a Balloon in the Stomach

1--balloon; 2--fistulous tube; 3--polyethylene tube; 4--plug that secures balloon in fistuluous tube; T_1--thermocouple that measures temperature in balloon; T_2--thermocouple that measures temperature of incoming water.

where c--specific heat capacity of water equal to 1; m--weight of water equal to 10 ml; T_1, T_3--temperature of water in balloon; T_2, T_4--temperature of incoming water. After thereaction of vascular constriction in the concha auriculae occurs we continued to introduce water so that the indicated reaction developed fairly distinctly.

The animal's temperature was recorded in the following body sections: hypothalamus, cerebral cortex, rectum, musculus latissimus dorsi, under the skin above it, back skin, skin of the concha auriculae, blood temperature in the aortic arch and in the anterior vena cava. Water began to be introduced into the stomach within an hour, after which all the temperatures reached a stable state. A drop in the temperature of the concha auriculae in our experiments served as a sign for the beginning of the thermoregulatory reaction of vascular constriction directed towards preserving heat in the organism. A total of 31 experiments were conducted on the three animals operated on by the method indicated above.

Study Results

By the beginning of the onset of vascular constriction in the

concha auriculae the quantity of heat expended by the animal's body for heating water in the stomach (Q') computed according to formula (1) averaged 266.9±21.5 cal/kg. Here the temperature of the conchae auriculae dropped by 2-6°. One of the typical experiments is presented in fig. 2.

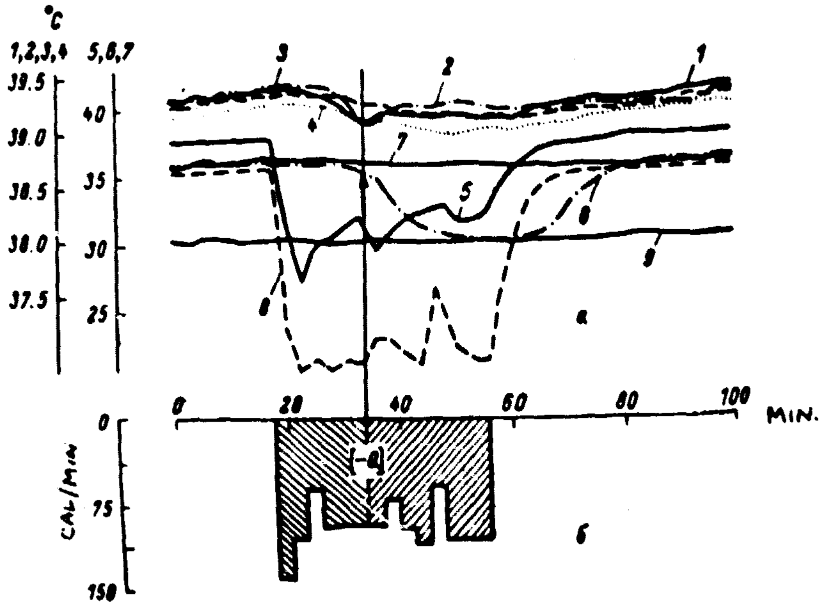

Figure 2. Effect of Introducing Water into a Balloon Located in the Stomach on the Temperature in Different Sections of the Body.
a--temperature; 1--blood in aortic arch; 2--rectum; 3--hypothalamus; 4--blood in the anterior vena cava; 5--in a balloon introduced into the rabbit's stomach; 6--skin of concha auriculae; 7--skin of back; 8--water entering the balloon; 9--chamber; b--heat given off by rabbit's body during its cooling by water introduced into the balloon.

The drop in the heat content of the animals' body by the beginning of the reaction was computed according to the following formula /845

$$Q = cm(T_5 - T_6). \quad (2)$$

where c--specific heat capacity of the live tissues averaging 0.83; m--rabbit's body weight; T_5--average body temperature in the

beginning of water entering the stomach; T_6--average body temperature at the moment the given reaction starts. The following temperatures were taken as the average body temperature: blood in the anterior vena cava, hypothalamus, rectum or liver. Here the calculated amount of change in heat content differed considerably from the actual heat losses. The blood temperature in the aortic arch reflected the value of the average body temperature in the given experiments the best. As the experiments and calculations showed, the change in body heat content, computed with the help of this amount reflects most accurately the actual heat losses of the body when the cooling water is introduced into the rabbit's stomach.

The amount of the heat threshold (Q') varied from experiment to experiment in limits of 227-386 cal/kg. We attempted to clarify the reason for such fluctuations. For this purpose a comparison was made of the levels of initial heat content in different experiments. A change in the heat content in the experiments with high threshold and in the experiments with low threshold was computed according to the formula $Q_1 = cm(T'_1 - T'_2)$, where c--specific heat capacity of the live tissues averaging 0.83, m--body weight of the rabbit, T'_1--blood temperature in the aortic arch in experiments with high thermal threshold in the beginning of water insertion into the balloon, and T'_2--blood temperature in the aortic arch in experiments with low thermal threshold in the beginning of water insertion into the balloon.

In the experiments with high thermal threshold, the initial heat content was always higher as compared to the experiments where the thermal threshold was low (table 1), and consequently, the rabbit had to give off more heat in order for the reaction of vascular constriction in the concha auriculae to occur. In those cases where the thermal threshold did not differ, the initial heat content coincided.

TABLE 1. EFFECT OF ORIGINAL HEAT CONTENT ON THRESHOLD QUANTITY OF HEAT GIVEN OFF BY ANIMAL'S BODY TO HEATING WATER IN STOMACH BY THE ONSET OF VASCULAR CONSTRICTION IN THE CONCHA AURICULAE

High thermal threshold (1) (cal/kg)	Low thermal threshold (2) (cal/kg)	Δ=1-2	Difference in initial heat content in experiments with high thermal threshold and in experiments with low thermal threshold (cal/kg)
386.8	303.8	83.0	124.0
386.8	257.6	129.2	156.9
386.8	227.3	159.5	224.0
303.8	257.6	46.2	33.0
303.8	227.3	76.5	98.9

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TABLE 2. CHANGE IN TEMPERATURE OF DIFFERENT BODY SECTIONS FROM BEGINNING OF INSERTION OF WATER INTO STOMACH TO MOMENT OF ONSET OF VASCULAR THERMOREGULATORY REACTION OF VASCULAR CONSTRICTION OF CONCHA AURICULAE MUSCLES

Site of temperature measurement	In beginning of water insertion into stomach, $M_2 \pm m$	At onset of reaction of vascular constriction of concha auriculae $M_2 \pm m$	$D_{M_1 M_2}$
Cerebral cortex (n=31)	38.76 ±0.04	38.52 ±0.04	< 0.05
Hypothalamus (n=31)	39.06 ±0.05	38.81 ±0.04	< 0.05
Rectum (n=31)	38.97 ±0.05	38.85 ±0.05	< 0.05
Aortic arch (n=11)	39.10 ±0.07	38.78 ±0.08	< 0.05
Anterior vena cava (n=24)	38.97 ±0.05	38.72 ±0.06	< 0.05
Liver (n=7)	39.21 ±0.08	38.45 ±0.14	< 0.05
Musculus dorsi (n=21)	38.39 ±0.11	38.24 ±0.08	> 0.05
Under back skin (n=20)	38.23 ±0.09	37.99 ±0.09	< 0.05
Back skin (n=31)	34.60 ±0.1	34.40 ±0.2	> 0.05
Water temperature in balloon (n=31)	36.50 ±0.1	30.40 ±0.2	< 0.05

From the beginning of cooling to the moment that the given reaction started there was a decline in temperature in different sections of the body (table 2). Thus, the cerebral cortex temperature dropped by 0.24±0.02°, the hypothalamus--by 0.25±0.02°, the rectum--by 0.12±0.01°, liver--by 0.7o±0.09°, musculus dorsi--by 0.15±0.03°, under the back skin--by 0.24±0.03°. The blood temperature in the aortic arch and in the anterior vena cava dropped respectively by 0.32±0.03 and by 0.25±0.01°. It is necessary to

note that by the time the concha auriculae vessels started to constrict, the temperature in the same body section in different experiments did not drop to an equal degree. Thus, table 3 presents two individual experiments on rabbit No. 3. It is apparent in a comparison of the temperature measurements in the aforementioned body sections that the temperature in all body sections, except the temperature in the blood of the aortic arch, dropped by a varying amount.Calculation of the quantity of heat given off by the animal's body demonstrated that in the first experiment, vascular constriction in the concha auriculae occurred with the release of 227.8 cal/kg of heat, and in the second--227.4 cal/kg. That is to say, with an equal threshold quantity of released heat the temperature changes in the indicated body sections differed almost two-fold. It is important to add that the skin temperature of the back in 13% of the experiments, temperature of the musculus dorsi in 9% of the experiments, and temperature of the rectum in 6% of the experiments remained unchanged, while in the other sections of the body it dropped. Based on what has been said it cannot be stated that the temperature change in any one section of the body is responsible for the engagement of the thermoregulatory vascular reaction. Analysis of the experimental data demonstrated that the onset of vascular constriction in the concha auriculae was not linked to any definite water temperature in the balloon /847 that was in the stomach. The minimum temperature in it at the moment the reaction started was 27.6° and the maximum was 33.2°. In separate experiments with an equal threshold quantity of heat given off by the animal's body by the beginning of vascular constriction, the water temperature in the balloon varied significantly. As is apparent from fig. 2, the maximum drop in temperature in the balloon did not induce a reaction immediately. A certain time was required, 17.0±0.8 min. in order for the body's heat content to drop and the vascular thermoregulatory reaction to begin that was directed towards heat preservation in the organism.

TABLE 3. CHANGE IN TEMPERATURE IN DIFFERENT SECTIONS OF THE BODY BY THE BEGINNING OF THE VASCULAR CONSTRICTION IN THE CONCHA AURICULAE

Site of temperature measurement	In beginning of water insertion into stomach (1)	At onset of vascular reaction (2)	Δ=1-2
	Experiment No. 1		
Cerebral cortex	38.98	38.72	0.26
Hypothalamus	39.41	39.04	0.37
Rectum	39.33	33.25	0.08
Aortic arch	39.37	39.08	0.29
Anterior vena cava	39.22	39.08	0.14
Musculus dorsi	38.81	38.68	0.13
Under back skin	38.53	38.33	0.20
Back skin	33.9	33.7	0.2
	Experiment No. 2		
Cerebral cortex	38.85	38.72	0.13
Hypothalamus	39.26	39.10	0.16
Rectum	39.36	39.20	0.16
Aortic arch	39.37	39.10	0.27
Anterior vena cava	39.25	39.02	0.23
Musculus dorsi	38.64	38.38	0.26
Under back skin	38.51	38.16	0.35
Back skin	34.1	33.7	0.4

Discussion of Results

An average drop in heat content by 266.3±26.2 cal/kg with ambient temperature of 28-30° induced the onset of the thermoregulatory reaction of vascular constriction in the concha auriculae. Under natural conditions of existence the heat content of the organism can drop under the influence of low ambient temperature, when drinking cold water, eating cold food, and reduced muscle activity. In computing the changes in the heat content it is necessary to know the average body temperature. Its determination undoubtedly represents great difficulties. In our experiments that were conducted with constant ambient temperature and with cooling of the animal by passing water throught the stomach, the change in the average body temperature to a great degree is reflected by the blood temperature in the aortic arch. The change in the organism's heat content that is computed from the drop in blood temperature in the aortic arch coincides with the threshold heat

quantity that is given off by the body of the animal and is computed from the temperature of the water introduced into the stomach. Consequently, when the organism is cooled from inside, the change in the average body temperature is a good reflection of the temperature of the blood emerging from the heart. The threshold amount of drop in the body's heat content that is necessary to start vascular constriction is on the same order as the threshold amount of increase in heat content at which the vascular dilation of the concha auriculae occurs, as was shown in our previous work [3,6]. During vital activity in the organism, often /848
there is an increase in the heat content, for example: during physical loads, under conditions of high ambient temperature, when eating hot food, during fermentation of food in animals' rumen.

Thus, both the increase in the body's heat content and its decrease to a certain threshold amount are accompanied by the engagement of the corresponding thermoregulatory reaction that is directed towards emitting heat in the organism (vasodilation in the concha auriculae) or its preservation (vasoconstriction in the concha auriculae).

In the literature on thermoregulation there are also statements on the important role of changes in the heat content in the emergence of thermoregulatory reactions. Snellen [15] found a linear relationship between the heat content of imbibed liquid and the sweating reaction in man. The author came to the conclusion that the regulating mechanisms are capable of measuring the quantity of heat. A model was suggested for human thermoregulation that is based on the hypothesis that the thermoregulatory system controls the level of heat accumulation in the body, but does not directly regulate the temperature of the heart [13].

One can hypothesize that the heat content is an integral amount that reflects the thermal condition of the organism, and is the object of regulation in the thermoregulatory system.

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